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VOLUME 1

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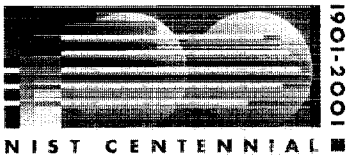

National Institute of Standards and Technology
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U. S. Department of Commerce
Norman Y. Mineta, Secretary
Technology Administration
Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology
National Institute of Standards and Technology
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DEVELOPMENT OF RESIDENTIAL SPRINKLERS AND ISSUES HIGHLIGHTED BY RECENT RESEARCH

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INTRODUCTION

A test program[1] was conducted at Factory Mutual Research from June 1978 to June 1979 to investigate the effects of sprinkler link sensitivity and water distribution characteristic upon sprinkler performance in typical residential fire scenarios. The test results show that sprinkler links that are significantly more sensitive than conventional industrial sprinkler links were essential in providing adequate life-safety and property protection in residential fires. A high-challenge, fast-developing fire scenario was identified. This scenario involved a shielded fire set in the corner of a ventilated living room having plywood paneled walls and a combustible ceiling. One residential sprinkler prototype proved successful in controlling fires in this ventilated living room test scenario. This prototype had a link with a Response Time Index[2] of 48 $(ft * s)^{1/2}$, (26.5 $(m \times s)^{1/2}$) a temperature rating of 140°F (60°C), and distributed adequate water to the walls and corners of the room.

Since sprinkler control of residential fires depends not only on sprinkler operation characteristics, but also on building geometry, ventilation condition and fire loading, the evaluation of sprinkler performance in a different building geometry was highly desirable. To accomplish this, a test program[3] was conducted to evaluate the prototype sprinkler in an actual residential dwelling. A two-story Spanish-stucco house located in Los Angeles, California was used for this purpose.

With data from these two programs, the NFPA 13D Subcommittee prepared a new version of the NFPA 13D Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes.[4] This version was adopted by NFPA in November 1980.

NFPA 13D STANDARD

Since 1980, the NFPA 13D Standard has undergone several cycles of revisions. However, the purpose of the standard has remained unchanged in the last twenty years. "The purpose of this standard is to provide a sprinkler that aids in the detection and control of residential fires and, thus, provides improved protection against injury, life loss and property damage. A sprinkler system designed and installed in accordance with this standard is expected to prevent flashover in the room of fire origin, where sprinklered, and to improve the chance for occupants to escape or be evacuated.[4]"

The standard requires that the system shall provide a discharge of not less than 18 gpm (68 ℓ/min) to any single operating sprinkler and not less than 13 gpm (49 ℓ/min) per sprinkler to the number of design sprinklers. The number of design sprinklers shall include all sprinklers within a compartment up to a maximum of two sprinklers under a smooth horizontal ceiling. The maximum area protected by a single sprinkler does not exceed 144 ft^2 (13.4 m^2). The maximum distance between sprinklers shall not exceed 12 ft (3.7 m) on or between pipelines, and the maximum distance to a wall or partition shall not exceed 6 ft (1.8 m). Furthermore, the minimum distance between sprinklers within a compartment shall be 8 ft (2.4 m).

In Appendix A of the Standard (Explanatory Material), it states that "the criteria in this standard are based on full-scale fire tests of rooms containing typical furnishings found in residential living rooms, kitchens and bedrooms. The furnishings were arranged as typically found in dwelling units in a manner similar to that shown in Figures A-1-1(a), A-1-1(b) and A-1-1(c).[4]" Figure A-1-1(c) represents the living room corner fire scenario used in the 1978-1979 FMRC test program.[1] A schematic drawing of this arrangement is shown in Figure 1.

The standard also permits application rates, design areas and areas of coverage other than those specified to be used with special sprinklers that have been listed for specific residential installation conditions, since it is not the intention of the standard to restrict new technologies or alternative arrangements. However, it is expected that any specific residential sprinklers listed by national recognized laboratories shall prevent flashover in the room of fire origin when they are tested in the living room corner fire scenario shown in Figure 1.

RECENT RESIDENTIAL SPRINKLER FIRE TESTS

Shortly after the adoption of the NFPA 13D 1980 Edition Standard, Underwriters Laboratories (UL) separately developed a fire test for their residential sprinkler standard (UL 1626[5]). The UL test compartment was constructed using combustible paneling and ceiling tiles. The fuel package included a wood crib placed over a pan containing heptane and foam supported by a wood stand, simulating upholstered furniture ends. The UL test arrangement is shown in Figure 2. The fuel package was designed by UL to simulate fire growth and shielding observed in the upholstered chair fire of the Los Angeles Residential Test Program.[3] During the time period since UL 1626 was first issued, UL has used this fire test to list special residential sprinklers over a wide range of spacings and flow rates.[6]

FMRC gained experience with the UL 1626 fuel package during a USFA-sponsored study investigating the feasibility of using water mist systems for residential fire protection.[7] In 1996, FMRC decided to adopt the UL 1626 residential fire test for its Approval Standard of residential sprinklers. In 1999, a series of fire tests was conducted to evaluate the reproducibility of fire test results utilizing the UL 1626 Residential Fire Test Standard. In response to UL's submittal of this standard for ANSI's recognition, five different models of UL listed residential sprinklers were evaluated at their respective listed discharge rates, one of which was the Grinnell F954

model (Model H in Table 1), which is representative of the prototype model used in the Los Angeles Residential Test Program. For all sprinkler models except Model F954, fire tests were conducted in an enclosure 16 ft wide, 32 ft long and 8 ft high as specified in UL 1626 for residential sprinklers installed on 16 ft spacing. For the F954 Model, a 12 ft wide, 24 ft long and 8 ft enclosure was used.

In all the tests of UL listed models at their respective listed discharge rates, only the F954 Model met the criteria for acceptability as specified in UL 1626. In all the other tests, a third sprinkler installed in the doorway actuated. In three of the tests, the tests were aborted less than two minutes after ignition of the wood cribs due to excess ceiling gas temperatures over ignition and observation of flames propagating across the ceiling and out the doorway closest to the fuel package. These conditions were judged to be indicative of imminent flashover. Results of the fire tests are presented in Table 1.

The Model A residential sprinkler was also tested using the living room corner fuel package shown in Figure 1. This test was conducted in the 16 ft x 32 ft x 8 ft high (4.88 m x 9.76 m x 2.44 m high) enclosure. Gas temperature and ceiling surface temperature over ignition and gas temperature at 5 ft (1.53 m) elevation at the room center are shown in Figure 3. Ceiling gas temperatures 3 in. below the ceiling at several locations are shown in Figure 4. After actuation of the sprinkler closest to the fire, the fire continued to grow and the gas temperature over ignition reached 1600°F (870°C). The second and the third sprinklers actuated 68 and 91 seconds, respectively, after first sprinkler actuation. Flames spread across the ceiling and out of the doorway farthest from the fuel package. Ceiling gas temperatures at the center of the ceiling reached 1000°F (540°C). Gas temperature at 5 ft elevation at the room center reached 220°F (100°C) at 1 minute 50 seconds after first sprinkler actuation. Large sections of the plywood panels in the room corner ignited and burned intensely. At 2 minutes after first sprinkler actuation, the test was aborted.

CONCLUSIONS

1. The fire test criteria of UL 1626 were not met in all tests conducted at listed densities equal or less than 0.055 gpm/ft^2 (2.2 ℓ/min/m^2) at first sprinkler operation.

2. One sprinkler, listed by Underwriters Laboratories for operation at 0.039 gpm/ft^2 (1.6 ℓ/min/m^2) for a single sprinkler discharge and 0.031 gpm/ft^2 (1.3 ℓ/min/m^2) for a two-sprinkler discharge, failed to prevent flashover in a 16 ft x 32 ft x 8 ft high (4.88 m x 9.76 m x 2.44 m high) compartment containing the FMRC living room corner fuel package.

3. A residential sprinkler fire test for listing of residential sprinklers should present a fire challenge comparable to that of the FMRC and the Los Angeles living room corner fire scenarios. The fuel package for the fire tests should consist of commercially available materials, which will have consistent flammability characteristics and be readily available through specification of chemical composition and means of manufacturing so that repeatability of the test can be achieved. As a result of the recent residential sprinkler test

program, UL and FMR have participated in a cooperative effort to develop such a fuel package during the last twelve months.

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Figure A-1-1(c) Living room.

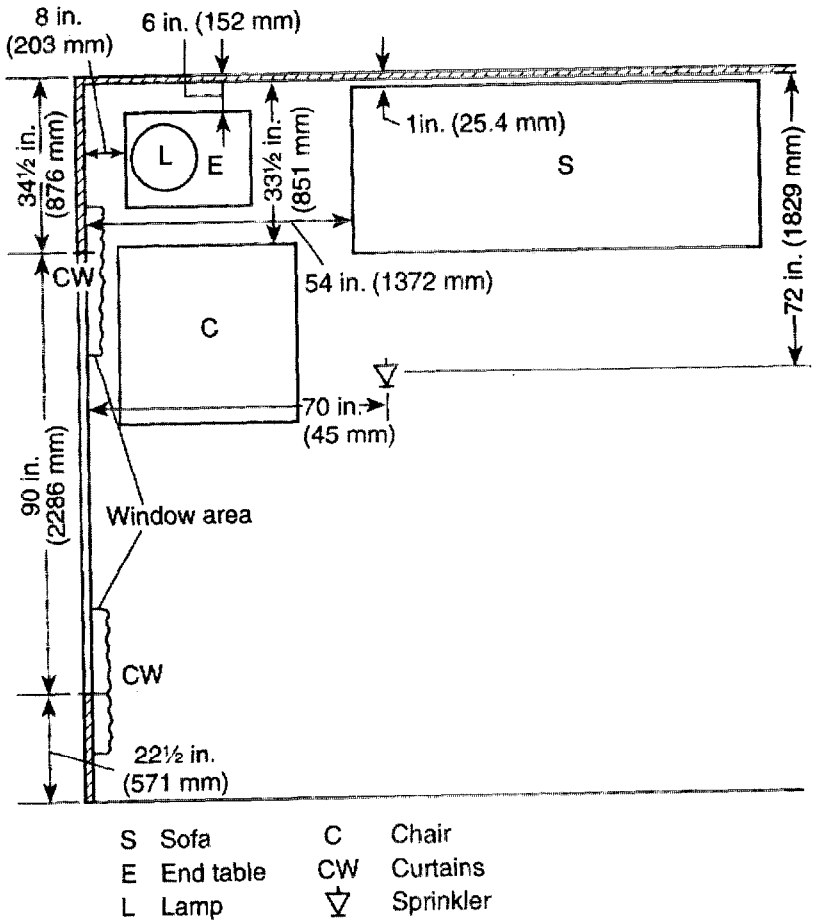

Figure 1. Living Room Corner Fire Scenario.

Figure 26.1
Fire test arrangement – pendent or upright sprinklers

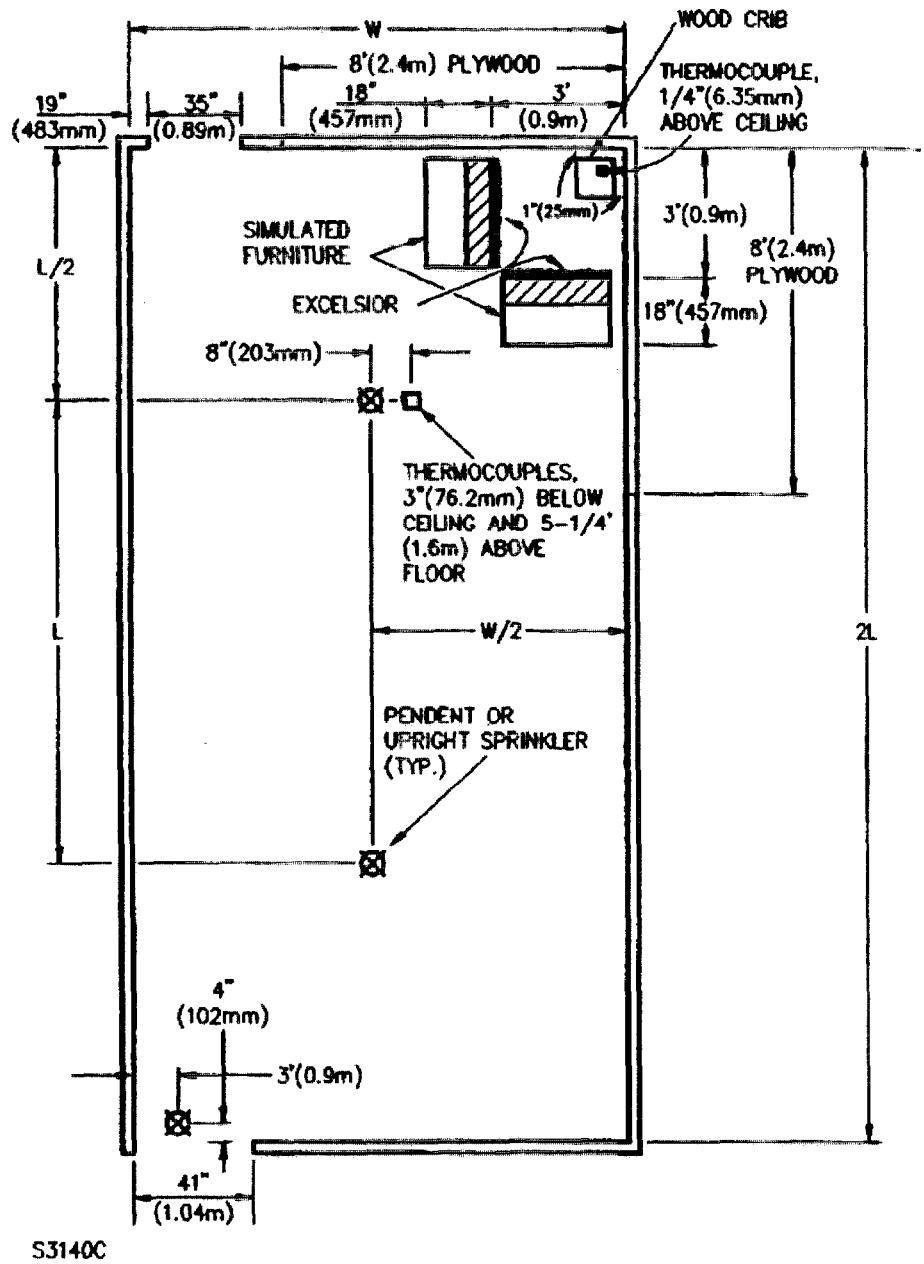

Figure 2. Schematic of UL 1626 Fire Test Setup (Reference 4).

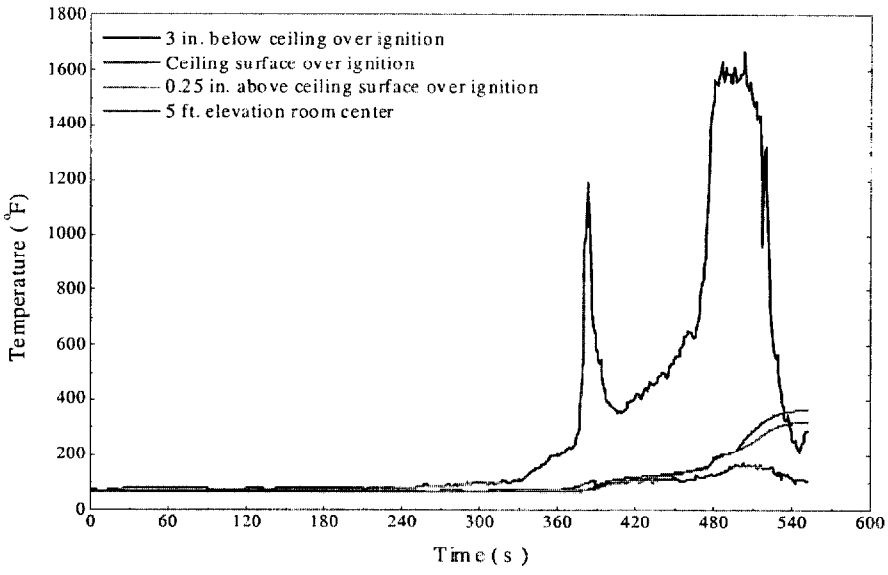

Figure 3. Temperatures over Ignition and at 5 ft in the Center of the Room. Model A at Listed Density, 0.039/0.031 gpm/ft^2, NFPA 13D Package in 16 ft x 32 ft x 8 ft High Room.

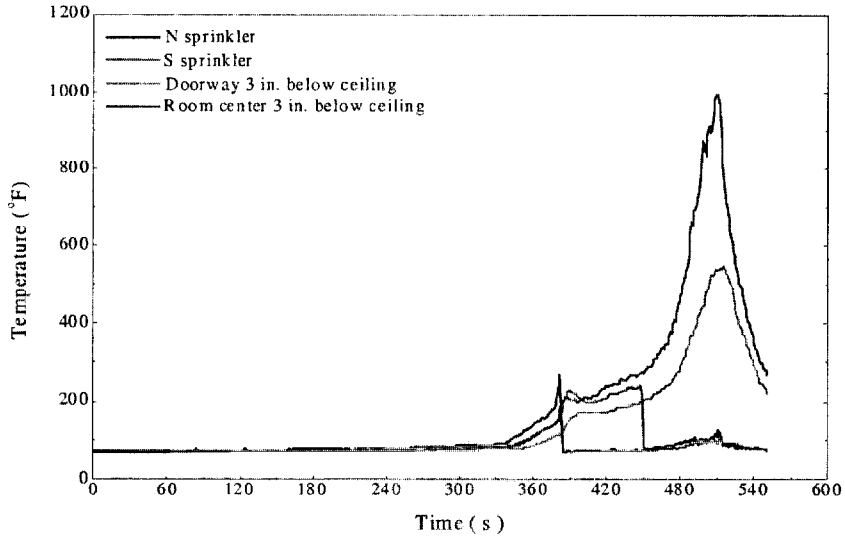

Figure 4. Gas Temperatures 3 in. below Ceiling. Model A at Listed Density, 0.039/0.031 gpm/ft^2, NFPA 13 D Package in 16 ft x 32 ft x 8 ft High Room.

Table 1. Factory Mutual Test Results Using UL 1626 Package

Sprinkler Model	Listing	K-Factor gpm/psi$^{0.5}$	Temp. Rating (^{o} F)	One/Two Sprinkler Total Flow (gpm)	Density for One/Two Sprinklers (gpm/ft^2)	Test Results When Tested with UL 1626 Test Package
A	UL	3.0	155	10/16	0.039/0.031	Test Failed / Flashover
B	UL	3.0	155	10/16	0.039/0.031	Test Failed / Flashover
C	UL	3.9	155	12/21	0.047/0.041	Test Failed / Flashover
D	UL	4.2	162	14/28	0.055/0.055	Test Failed / 3rd sprinkler operated
H	UL	2.8	165	18/26	0.125/0.09	Test Passed